EXPLORING COMMERCIAL THINNING OPPORTUNITIES IN ARROW AND CRANBROOK TSA

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EXECUTIVE SUMMARY

Timber Supply Reviews (TSR 1) and the implementation of the Forest Practices Code and Kootenay Boundary Land Use Plan, indicate that the allowable annual cut in the Nelson Forest Region may be reduced by 13.3%-21.7 %. Commercial thinning may offset some projected wood supply fall downs through improved harvesting flexibility.

The main objectives were: 1) Complete an overview analysis of suitable forest types and candidate stands for commercial thinning, 2) Complete a field inventory of a portion of the themed stands to determine their suitability for thinning, and 3) Test the impact of different levels of thinning on wood flow in Arrow Timber Supply Area (TSA) using a modified FSSIM harvest forecast model.

Locally-developed inventory, utilization and economic suitability criteria were used to identify and theme map potential areas in the Arrow and Cranbrook TSAs. Reconnaissance surveys were conducted in a portion of the themed stands. Stands that met minimum suitability criteria were cruised to determine potential harvest volumes and residual stands conditions. District staff reviewed the cruising results, and after follow-up field inspections, selected the actual stands that would later be thinned.

Theming initially identified approximately 44,557 hectares in the Arrow and 24,843 hectares in Cranbrook. Lack of road access subsequently eliminated approximately 85-90% of the themed stands as potential candidates for thinning. Reconnaissance surveys in the accessible stands indicated that approximately 80-90% of the stands surveyed were unsuitable for thinning, mainly due to inappropriate stand structure or low potential thinning volumes. Only a subset of surveyed stands was cruised in each TSA. The cruising identified between 10,298 and 14,195 m^3 of potential thinning volume in Arrow and 32,650 to 41,704 m^3 in Cranbrook, depending on the minimum utilization level. However, District staff anticipate that only 40-60% of the cruised stands may actually be thinned due to stand structure and overriding management objectives.

Resource Emphasis Area management objectives, current stand structure, biological potential of the stand to maintain adequate growth after thinning and utilization level by species must all be considered when developing thinning prescriptions. There are trade-offs between potential thinning volume, stand growth and forest health depending on the emphasis of any of these factors.

In the Arrow TSA, a 2-5% increase in short term wood supply was indicated by the modelling when the thinning was concentrated in visually constrained Resource Emphasis Areas. The positive effects on wood flow were maximized at 400 hectares per year but were only sustainable for the first six decades. The increase in wood flow attributed to commercial thinning is not additive to the increase from other partial cutting practices in constrained areas. Some of the benefits may already be realized due to the amount of partial cutting currently being practised.

Recommendations are made for future projects of this nature.

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1. INTRODUCTION

The last cycle of Timber Supply Reviews (TSRs) reduced the Allowable Annual Cut (AAC) in the Nelson Forest Region from 6.0 million m3/year to 5.5 million m^3/year. The implementation of the Kootenay Boundary Land Use Plan (KBLUP) is expected to reduce the AAC to between 4.7 and 5.2 million m^3/year. This represents a 13.3%-21.7% drop in AAC. The implementation of the KBLUP also includes a projected loss of 460-560 direct jobs and $10.5 million of direct stumpage per year.

A greater reliance on partial cutting systems, compared to clearcutting, may minimize the wood supply fall downs while addressing the management requirements of other resources. Although partial cutting is already being practised to varying levels in each Timber Supply Area (TSA) (Hawe 1996, Listar et al. 1998), the effects of partial cutting were not directly modelled in the most recent TSRs (TSR1) conducted by the Chief Forester. Additionally, the Chief Forester, in his AAC determination and rationale statements for five of the seven TSAs in the Nelson Forest Region, indicated that before commercial thinning impacts could be considered in future TSRs, candidate commercial thinning stands must be identified, a commercial thinning strategy must be developed and the impacts of a commercial thinning program on timber supply must be assessed.

Commercial thinning is a form of partial cutting that is defined as the removal of a portion of the trees in which all, or a portion, of the felled trees are extracted for useful products, regardless if their value is great enough to defray the cost of the operation (Smith 1962). Commercial thinning is typically done in stands that are not mature or that are younger than the minimum harvest age.

At the stand level, commercial thinning can:

a) redistribute the growth potential on selected crop trees,
b) utilize all the merchantable material produced from a stand including salvaged mortality,
c) increase the value of the final crop, through increased log sizes, while lowering its harvest and milling costs,
d) improving stand vigour and lowering the risk of future pest losses and sometimes increasing yield (Ministry of Forests 1994, Johnstone 1997).

Also at the stand level, computer simulations have shown that productivity can be maintained or slightly improved through careful development of partial cutting regimes. If not planned correctly, commercial thinning will reduce the cumulative volume (Johnstone 1997, Ministry of Forests 1994, Robinson *et al.* 1996, Stone, 1995).

At the forest level, commercial thinning can:

a) deliver wood earlier than harvesting at culmination ages
b) alleviate wood supply shortages by addressing age class imbalances, and lengthening technical rotations.

c) achieve integrated resource management (IRM) objectives such as visual quality and greenup and

d) dampen fluctuations in timber supply while keeping mills open, employing people and stabilizing communities through earlier wood supply(Ministry of Forests 1994, Johnstone 1997).

This project addresses some of the Chief Forester's recommendations in the context of the recently-approved Kootenay-Boundary Land Use Plan by providing a framework for developing a commercial thinning strategy using Arrow and Cranbrook as pilot TSAs. The framework can be modified to suit the specific conditions and objectives of other TSAs as required. It consists of identifying utilization and economic criteria, theme mapping to identify potential areas, field inventories of potential areas to identify actual candidate stands and wood supply modelling to test the effects of various levels of commercial thinning on wood flow. The results of this approach in the two pilot TSAs are discussed and recommendations are made for future projects of this nature.

2. OBJECTIVES

The main objectives of this project were to:

1. Complete an overview geographic information system (GIS) theming analysis of suitable forest types and candidate stands for commercial thinning in the Arrow and Cranbrook TSAs

2. Complete a field inventory of a portion of the themed polygons, using locally-developed suitability criteria to determine their suitability for commercial thinning

3. Test the impact of different levels of commercial thinning on wood flow in the Arrow and Cranbrook TSAs

Additionally in Arrow TSA, District staff thought that the Summit Lake Area, south of Nakusp, had potential for commercial thinning. If the expected potential was confirmed, then a commercial thinning plan would be developed for the area.

Additional objectives for the Cranbrook TSA included:

1. Quantify/describe the population of stands suitable for commercial thinning
2. Identify and locate sufficient stands for two years of operational commercial thinning
3. Demonstrate to Forest Renewal BC the potential of commercial thinning in order to secure funding for future related projects
4. Use the information obtained in this project to promote and support a potential commercial thinning program in the next Timber Supply Review

3. METHODOLOGY

3.1 ARROW TSA

3.1.1 Overview of Geographic Information System (GIS) Theming

Arrow District staff district staff supplied the following priorities for theming:

Priority 1: -Age class III - V (41-100 years old) with a component of white pine. The reason is to identify and salvage potential mortality caused by white pine blister rust, *Cronartium ribicola*
-Previously spaced
-In landscape units (LUs) with recommended visual quality objectives of retention (VQO-R) and partial retention (VQO-PR).

Priority 2: -All stands in the Interior Cedar Hemlock (ICH) biogeoclimatic (BEC) zone below minimum harvest age as defined in the Arrow TSR. Minimum harvest ages in the TSR range from 70 - 90 years for lodgepole pine, 80-120 for Douglas-fir, and 90 - 140 ears for other species.

These immature stands are assumed to have sufficient sawlog volume for a commercial thinning entry.

Priority 3: -All age class III-V, ICH stands where deciduous tree species are a major stand component. These stands may have sufficient volumes of white birch to meet the demands of a sawmill. The birch and some of the conifers would be thinned, while the majority of conifers would be left for the final harvest.

The District does not have a formal TSA Steering Committee, but does have an informal process for obtaining Licensee input into planning, through the Arrow Forestry Association (AFA). A survey, Appendix A, was distributed to all Licensees in the AFA requesting them to identify preliminary biological and economic stand selection guidelines for commercial thinning because:

1) most of the Small Business Forest Enterprise Program(SBFEP) wood is sold to the representative licensees, therefore the products of the commercial thinning (e.g.: species, minimum top diameter) must be compatible with mill requirements and

2) it was assumed that the SBFEP contractors used the same economic criteria for harvesting as the licensees

3) there was no AFA meeting scheduled in the near future, and the issue of commercial thinning could not be addressed with all the Licensees present at the same time.

Only one licensee provided survey information, and confirmed that age class III-IV with a component of white pine were high priority stands for thinning. Consequently, no additional theming was required to incorporate licensee priorities.

Peter Lewis, Land Information Planning Officer, prepared the overview colour theming for potential candidate stands on Crown land within the operable land base. A colour-themed map at a scale of 1:250,000 was developed showing the potential areas within the TSA based on information in the inventory Forest Inventory and Planning (FIP) files. A complimentary summary report was produced that identified potential area by LU, BEC zone, slope class and mapsheet polygon. The Slocan Forest Products and Pope & Talbot tree farm licences (TFLs) were not included in the analysis because they are not within the boundaries of the TSA.

Additional colour-themed forest cover maps, at a scale of 1:50,000, were developed for the Glade, Stagleap, Erie, Bear and Ymir LUs and the Summit Lake area, south of Nakusp, which the District had targeted for a more intense analysis of commercial thinning opportunities. These LUs contain relatively larger areas of themed stands, have high to moderate constraints to clearcutting, are close to mills and contain SBFEP operating areas. They were also identified by the Salmo and Area Economic Development Commission as having commercial thinning and other intensive forestry opportunities (Anonymous 1997). Stands that were adjacent to existing roads were then selected for a field reconnaissance survey to verify their potential for commercial thinning.

3.1.2 Field Inventory

The field inventory was divided into two phases: i.e. the reconnaissance survey and the cruise. The purpose of the preliminary reconnaissance surveys was to identify those themed stands that were definitely not candidates and those that may be suitable for commercial thinning. The reconnaissance survey involved a walkthrough of representative areas within the themed stands. Formal plots were not established. The commercial thinning potential was based on the collective experience and professional judgement as to the biological suitability and an estimate as to the economic feasibility. The reconnaissance surveys were completed by Dan Reibin (Forest Health Technician), Arnie Erickson (Silviculture Forester), Tom Johnston (Silviculture Officer) from the District office and Ivan Listar (Silviculturist) from the Regional office.

The stands that were considered suitable for commercial thinning were then included in a cruising contract to collect more detailed stand information. Because of limited available field time and the assumption that the "best" opportunities to identify potential candidate stands would be found in the coniferous-leading stands, the deciduous-leading (priority 3) stands were not sampled.

Biological criteria used in the reconnaissance phase included:

- species composition of the current and residual stand after the commercial thinning
- % live crown of the residual crop trees as an indicator of the trees' ability to maintain or increase diameter growth after treatment

- height/diameter ratio of the potential residual crop trees as an indicator of wind and snow stability
- pest incidence assessment and evaluation of future risk
- age of stand and potential residual crop trees

Economic criteria used in the reconnaissance included:

- LUs where clearcutting is constrained due to visual quality objectives
- species to be removed, as some species such as lodgepole pine are preferred over others for manufacturing
- minimum estimated volume of 70m^3/ha which could be harvested and still retain a stocked stand after thinning
- slopes less than 35%
- minimum road development to, and within, the stand
- distance to mills

The cruise phase further refined the surveyed stands for which commercial thinning would be considered. The cruise parameters included standard criteria and additional, specific silvicultural information required for future Silviculture Prescription (SP) development and stand growth modelling using the PrognosisBC stand growth model. The cruisers were instructed to identify potential cut and residual trees based on defined suitability criteria. They were to leave a residual basal area (RBA) of 10 - 15 m^2/ha and approximately 600 - 800 well-distributed trees per hectare in tree layers 1 and 2 (layer 1: greater than or equal to 12.5 cm DBH; layer 2: between 7.5 and 12.4 cm DBH) at a minimum 4m inter tree distance. Those stands that had the "best" combination of economic and biological potential would then be selected for commercial thinning sales to be issued by the SBFEP. A copy of the cruising contract specifics is shown in Appendix B.

The cruising was done under contract by Kokanee Forest Consulting Ltd. of Nelson. As commercial thinning is a new concept in the Arrow TSA, District staff and this author accompanied the cruising crew on the first day of field work to ensure that the crew understood the objectives, cut/leave parameters and other specifics of the contract. Accompanying the cruising crew was critical to the success of the cruising phase, and resulted in obtaining the required information.

3.1.3 Wood Supply Modelling

The wood supply modelling examined the effects of commercially thinning 200, 300, 400, 500 and 600 hectares per year on wood flow in the Arrow TSA within the context of the KBLUP. This is the first time that this type of analysis was conducted within the context of an approved land use plan. A more detailed description of the methodology and assumptions is available in Wang and Pollack (1998).

TIPSY (Table Interpolation rather than VDYP (Variable Density Yield Projection) yield curves were used because they more closely reflected expected stand volumes and thinning yields. Very simple stand level treatment scenarios and response functions were developed because the objective was to study the effects of commercial thinning on forest level dynamics and not stand level responses. One major assumption was no total volume removal difference between the commercial thinning regime and a one pass clearcut regime which was used in the baseline analysis.

At the forest level, the most recent TSR netdown and analysis unit assumptions were applied along with the management parameters defined in the KBLUP. The KBLUP parameters included:

- Landscape unit boundaries
- Biodiversity emphasis assignments and seral stage requirements
- Resource emphasis area boundaries and forest cover requirements

The treatment scenarios and assumptions for the Arrow TSA are detailed in Table 1. Based on the suitability, growth and management assumptions, thinning yields varied from 50 - 138 m^3/ha depending on timber type, thinning age and analysis unit. The potential area available for thinning was 40,946 hectares.

The FSSIM (Forest Service Simulation) harvest forecast simulation model was used to complete the baseline and commercial thinning analysis. The standard FSSIM version 1.0 has limited capability to model the effects of partial cutting and commercial thinning. The Ministry of Forests Timber Supply Branch modified this standard version and an experimental, prototype (FSSIM version 2.2.1) that better remodelled the effects of partial cutting, was used for this analysis.

A baseline wood flow using clearcutting only, was first completed. The commercial thinning effects were then measured against this baseline. Any changes to the wood flow from the clearcutting baseline could then be attributed to changes in timing or availability of the wood due to commercial thinning

3.2 CRANBROOK TSA

3.2.1 Overview of Geographic Information System (GIS) Theming

The Cranbrook District examined the commercial thinning potential in major leading timber types across the entire TSA before identifying specific geographic areas or LUs for additional analysis. In addition to leading species, they wanted to examine specific inventory stand attributes (eg: height class, stocking class, etc.) to determine if these attributes are useful in selecting potential thinning areas at the landscape level. Inclusion of these attributes resulted in a different approach to theming than for the Arrow TSA.

Table 1. Treatment scenarios and assumptions used in modelling the effects of commercial thinning on wood supply in the Arrow TSA

Treatment scenario	Arrow TSA
Location	Landscape units with moderate to high levels of visual quality constraints
Target stand leading species	Lodgepole pine (G,M sites) - analysis unit 1 Douglas-fir (G,M sites) - analysis unit 7
Slope	</= 40%
Minimum and maximum ages when stands can be thinned	Thinning window 1 - age 41-60 Thinning window 2 - age 61-80 Thinning window 3 - age 81-100
Minimum merchantability at thinning	12.5 cm for pine 17.5 cm for other species
Stand volume removed during thinning	50%
Minimum merchantability at final harvest and for clearcut stands	12.5 cm dbh
Final harvest system	Clearcut
Expected growth response to thinning	MAI unchanged compared to clearcutting - total harvested volume of thinning and final harvest equals volume at culmination age if the stand was clearcut
Time between thinning and final harvest	Window 1 - minimum 50 yrs Window 2 - minimum 40 yrs Window 3 - minimum 30 yrs
Minimum final harvest age for thinned stands	age 91-111 depending on the initial thinning window
Effect of thinning on management constraints	No impacts except on biodiversity
Effect of final harvest and clearcutting on management constraints	Full impact on all constraints

The theming was done in four phases. The first phase was a broad, TSA wide overview using many stand attributes. The second phase addressed some discrepancies found in the first phase. The third phase involved at a smaller number of attributes and stand types. The fourth phase examined the potential in three specific LUs.

The attributes to be themed resided in various unrelated databases. Regional GIS staff provided the required FIP, TRIM and other non-standard databases to a local contractor for production of the theme maps and complimentary reports. The contractor used the Foxpro (Anonymous, 1991) database management program to import the required theming attributes from the various databases in order to produce one operational database for this project.

Because of the large number of attributes to be examined, a paper base map of the TSA, at a scale of 1:125,000, showing specific features, was created. A series of transparent acetate overlays for the base map, each showing specific attributes, was then created so that any combination of species, stand attributes and other parameters could be examined.

The features shown on the base map included:

- operable and inoperable landbase as defined in the TSR
- ESA's - environmentally sensitive areas by type
- water features such as rivers, lakes, etc.
- Crown forest (ownership groups 61C, 62C, 69C and 76N) and alienated
- lands such as parks and private land
- inventory mapsheet boundaries

Additional transparent acetate overlays were produced for landscape units as defined in the KBLUP, road networks, and BEC zones and subzones. For each of the four major tree major species, a specific acetate overlay was created to show each of the stand attributes either separately or in combination. The attributes were differentiated by colour or cross-hatch patterns and are detailed below:

- Douglas-fir inventory type groups 1-7
- lodgepole pine inventory type groups 28-30
- yellow pine inventory type group 32
- western larch inventory type groups 33, 34
- age classes 3, 4, 5 (ages 41-60, 61-80, 81-100 respectively)
- height classes 2, 3, 4 (10.5-19.4m, 19.5-28.4m, 28.5-46.4m respectively)
- stocking classes 2, for all species except lodgepole pine (for mature trees: <76trees per hectare, 27.5 cm^{+} d.b.h.)
- stocking classes 3 and 4 for lodgepole pine only (for mature trees: $\geq$ 311 per hectare, 17.5cm^{+} d.b.h. and 50% of the stems 7.5cm^{+} d.b.h. are $\geq$ 12.5 cm d.b.h.: < 311 per hectare, 17.5cm d.b.h., or, $\geq$311 per hectare 17.5cm d.b.h. and < 50% of the stems 7.5cm^{+} d.b.h. are $\geq$12.5cm d.b.h. respectively)
- crown closure class grouped by classes 0-2, 3-5, 6-7 and 8-10
- site classes good, medium, and poor

Summary reports of various combination of attributes were produced indicating the area of those combinations by LU, BEC subzone, inventory mapsheet, leading species and age class.

The first phase review of the base map and species overlays showed significant discrepancies with current inventory forest cover maps, BEC subzone and LU boundaries. Many stands of a particular age class that were identified from the theming often corresponded with stands that were one age class older on the inventory forest cover maps. The discrepancies were attributed to a difference between the age at the time of the inventory update and the projected current age. The data used for the theming was based on 1989 inventory update, and used the ages as of that year. However, the forest cover maps were updated in 1994 and used the projected ages based on the 1989 inventory update. For example, a stand that was considered 57 years old in the 1989 inventory was themed as age class 3 (age 41-60 years old), while the forest cover map indicated its projected age age class 4 (57 + 5 = 62 years old). Some BEC subzone and LU boundaries had also been revised at the district level but the changes had not yet been incorporated into the regional database. As a result of the discrepancies, the theme mapping and resultant reports were revised using the projected age classes and updated information before detailed analysis of the commercial thinning potential could be completed.

The second phase included a review of the revised theme maps and reports. Additional refinements of the stand attributes and other parameters were made by district staff in order to better identify potential candidate stands. Lodgepole pine and Douglas-fir were identified as the predominant species in the TSA, with yellow pine and western larch only locally important. Age class 5 is above the minimum harvest age used in the TSR and was considered too old for commercial thinning. The height and stocking classes were not considered reliable indicators of commercial thinning potential. Also, previous discussions with licensee members of the TSA Steering Committee indicated that the best opportunities for commercial thinning were in lodgepole pine and Douglas-fir stands with less than 40% slope.

The more specific phase three theming was completed by Nelson Forest Region GIS staff. The attributes and parameters included:

- lodgepole pine leading species
- Douglas-fir leading species
- age classes: 3, 4
- site classes: good and medium
- crown closure classes: 6, 7 (56 - 75% crown closure)
- slope: <40%

After reviewing the results of this level of theming, the district staff selected three LUs for detailed review and field verification of potential sites. These LUs were Moyie Lake (C1), Cranbrook (C30), and Lost Dog-Mather (C31). These LUs were selected because of:

- proximity to existing sawmills
- access
- relatively large areas of potential stands
- moderate to high constraints to clearcutting
- they contained operating areas for major licensees and SBFEP

The phase four theming included a separate 1:50,000 inventory forest cover map of the three LUs highlighting the stands that met the above-listed attributes. NSR (Not Satisfactorily Restocked) areas were also highlighted to assist in identifying those potential stands constrained from clearcutting because of adjacent NSR stands. A summary report identifying suitable polygons and area was developed for each LU.

3.2.2 Field Inventory

Potential stands for field verification in the three LUs were identified by Cranbrook district staff from the LU theme maps. Additional stands, with similar attributes in adjacent LUs, were also identified for field verification. Because of budget limitations, not all the potential stands in any LU could be verified.

Biological and economic criteria for determining suitability for commercial thinning were based on past experience, professional judgement and licensee input at previous TSA Steering Committee meetings. Suitability criteria for commercial thinning included:

- Stocking density of 700 stems per hectare or more
- Crown closure class of 4 or more
- Site index of > 11m at breast height at age 50
- Live crown of the dominant and codominant trees > 20%
- Height/diameter ratio of dominant and codominant trees < 100
- Less than 10% of the dominant or codominant trees exhibiting above-ground symptoms of *Armillaria* root rot
- Minimum size of treatment area of 10 hectares
- Slope < 40%
- Within 250m of existing road access

Both the field reconnaissances and cruising were done under contract by Interior Reforestation Co. Ltd. The contractor completed a walkthrough reconnaissance of each stand to first determine whether the stand met the minimum thinning suitability criteria detailed above. If the stand was not considered suitable, the contractor established a minimum of 2 cruise plots in representative areas of the stand and completed a one page summary report detailing the reasons to support the determination and reclassification of the inventory stand label if required. The stands that were determined to be not suitable for commercial thinning were further categorized into potential sawlog or pulpwood stands depending on attributes provided by licensees (Table 2). If the stand met the minimum suitability criteria, the contractor completed a cruise at an intensity of one plot per 2.5 hectares to collect additional information required for future prescription development, valuation purposes and stand growth modelling. A copy of the contract schedule is included in Appendix C.

Table 2. Stand suitability criteria for commercial thinning in the Cranbrook TSA.

Stand Attribute	Potential Sawlog Category 1	Potential Sawlog Category 2	Potential Pulpwod Category 1
Stocking	≤ 600 trees per hectare	Between 660 and 3000 trees per hectare	>3000 trees per hectare
Crown closure	≤ crown closure class 4	> crown closure class 4	N/A
Age	> 80 years old	≤ 80 years old	N/A
Site index	>11 m at breast height age 50 years	>11 m at breast height age 50 years	<11 m at breast height age 50 years
Height/diameter ratio of dominant and codominant trees	≤ 100	≤ 100	> 100

3.2.3 Wood Supply Modelling

The original objective was to examine the results of different levels of commercial thinning on wood flow. Due to timing and funding constraints, the effects of commercial thinning were not specifically modelled for the Cranbrook TSA, although related modelling effects of partial cutting are reported in Wang and Pollack (1998).

4. RESULTS AND DISCUSSION

4.1 GIS Theming

4.1.1 Arrow TSA

The GIS theming was completed by Peter Lewis, Planning Officer, Arrow Forest District. Based on the initial inventory theming criteria there are approximately 87,758 hectares of potential commercial thinning area available on all slopes and within all BEC zones. When the area was constrained by a maximum 35% slope and to the ICH BEC zone, this potential was reduced to 41,303 hectares of priority 1, 2 and 3 stands (Table 3). There was considerable variation in the potential area between landscape units, ranging from zero to over 9,000 hectares. This potential is still considered optimistic as access, distance to mills, minimum stand size, suitable stand structure and some other economic factors could not be adequately themed.

Additional, or more specific, theming criteria from the inventory FIP files and GIS database can be used to refine the potential candidate stands or eliminate unsuitable stands. However, because of discrepancies found later during the reconnaissance and cruising stages, between the stand attributes in the inventory files and actual stand conditions, additional parameters may not necessarily facilitate the identification of potential stands. Some refined criteria recommended by District staff include, but are not limited to:

- timber type (e.g.: distinguish between white birch and other deciduous leading species such as aspen and cottonwood)
- site index >11 to eliminate poor and low sites
- crown closure class >3 (unless the stand has been spaced) to eliminate open, poorly stocked stands
- environmentally sensitive areas (ESA) to be removed due to high risk
- refined slope classes
- refined age ranges
- specific Resource Emphasis Areas (e.g.: VQO-retention, community watersheds, etc.)
- minimum stand polygon size
- distance from mills (can be roughly approximated by using inventory mapsheets as surrogates) (Arnie Erickson, pers. comm. 1998)

Accessibility of potential stands was an issue that could not be directly addressed by the theming and approximately 10-15% of the themed stands had road access shown on the forest cover maps. Theme maps at small scales (i.e.: 1:250 000) were useful for identifying large concentrations of certain themed types, however, they are unsuitable for showing the access. At small scales, maps are too cluttered and the road systems are unclear. The accessibility of stands must still be determined from larger scale maps, such as 1:50 000 and 1:20 000, using a combination of visual assessment of the stand location in relation to the roads and local knowledge of the road conditions.

Table 3. Results of commercial thinning theming for Arrow TSA by Landscape Unit (LU) and priority ranking. All stands between 41 years of age and the minimum harvest age, within the ICH biogeoclimatic subzone, and slopes less than 35%

Landscape Unit		Priority 1 41-100 years old			Priority 2 >41yrs old and < minimum harvest age	Priority 3 >41yrs old and < minimum harvest age Deciduous component > 20%	Other Deciduous	Total
#	Name	Stands with white pine	Previously spaced	In VQO - R & PR Resource Emphasis Areas				
A1	Big Sheep	294	0	0	2 238	261	187	2 980
A2	Lower Columbia	189	0	0	949	95	188	1 421
A3	Beaver Valley	683	0	0	1 718	271	273	2 945
A4	Pend' Oreille	194	0	0	999	347	43	1 583
A5	Erie	1 161	63	0	2 739	330	646	4 939
A6	Salmo	376	189	161	1 416	363	196	2 701
A7		209	0	0	264	31	216	720
A8	Blueberry	611	7	7	1 867	268	28	2 788
A9	Champion-Glade	103	116	0	2 869	154	88	3 330
A10	Ladybird	280	0	24	1 316	56	147	1 823
A11	Cayuse-Deer	7	62	161	630	7	0	867
A12	Shields- Dog	23	0	0	1 384	14	27	1 448
A13	Renata	0	0	0	0	0	0	0
A14		3	0	0	16	0	2	21
A15	Octopus	0	0	0	0	0	0	0
A16	Koch	0	0	0	0	0	0	0
A17	Perry Ridge	14	0	46	444	32	21	557
A18	Slocan	208	0	119	283	6	19	635
A19	Burton	8	0	0	123	14	19	164
A20	Eagle	255	0	156	7 749	512	435	9 107
A21		0	0	0	0	0	0	0
A22	Whatshan	0	0	0	226	39	31	296
A23	Mosquito	208	0	0	294	5	15	522
A24	Caribou	171	0	6	338	17	0	532
A25	Bonanza	770	6	147	953	97	495	2 468
A26	Wilson	63	7	0	295	14	26	405
A27	Kuskanax	321	0	5	315	3	0	644
A28	Fostall	0	0	0	0	0	0	0
A29	Halfway	0	0	0	38	0	0	38
A30	Trout	19	0	0	246	23	34	322
A31	Incomappleux	129	0	0	23	106	2	260
A32		0	0	0	0	0	0	0
A33		0	0	0	0	0	0	0
A34	Silverton	154	0	139	266	48	67	674
A35	Lemon	105	0	8	205	0	49	367
Total		6 558	450	979	30 203	3 113	3 254	44 557

There was a small difference of approximately 357 hectares between the potential area in the theming phase and that used in the modelling phase for the following reasons:

- different stand suitability criteria (e.g.: 35% vs. 40% slope used in the modelling)
- amalgamation of stand types to allow compatibility with TSR and KBLUP analysis units for modelling
- selection of stands from VQO REA's only for the modelling but not the theming

4.1.2 Cranbrook TSA

The preparation of the databases and the initial broad level GIS theming was completed under contract by Geo-Grafix Information Systems Ltd. The broadest level of theming, based on the initial stand attributes, identified approximately 238,542 hectares of lodgepole pine, Douglas-fir, larch and yellow pine stands between 40 and 100 years of age on all site classes across the TSA.

When more specific stand attributes and theming parameters were used, approximately 24,843 of potential candidate stands were identified. The results are detailed in Table 4. The potential area ranged between zero to 3,147 hectares in any particular LU.

Based on information collected at the reconnaissance and cruising stages, there is potential to refine existing, or include new, theming parameters to filter out unsuitable stands and reduce the number of surveys (Bill Olsen, Tom Hedin, pers. comm. 1998). Some of these parameters include, but are not limited to:

- all mixed species stands with a 30 - 50% component of lodgepole pine
- all stands 20 - 70 years old in 10 year increments
- all stands that have been juvenile spaced
- all stands with a minimum site index >17

Regardless of theming criteria used, lack of road access was the main reason for eliminating potential candidate stands. Approximately 90% of the themed stands had no identifiable road access (Bill Olsen, pers. comm. 1998) and were eliminated from additional exploration of their suitability. Changing the road access criteria (e.g.: define accessible as within 1.5 km of a road) may produce a higher percentage of candidate stands for reconnaissance surveys and a better estimate of the potential area suitable for commercial thinning. However, there is a trade-off, because the additional cost of road building may result in candidate stands becoming uneconomic to harvest at this time. With additional road development and second growth managed stands becoming suitable, this themed/accessible ratio may improve in the future (Tom Hedin, pers. comm. 1998). ***In the short-term, 5-year development plans and Integrated Watershed Restoration Plan access management maps can be used to determine where new access will be planned or existing access adversely affected. Themed stands can then be reassessed for accessibility.***

Table 4. Potential hectares of themed candidate stands for commercial thinning in Cranbrook TSA by Landscape Unit (LU). Criteria were based on leading species, age, site class, crown closure class 6 and 7, and slope < 40%.

Species		Lodgepole pine				Douglas-fir				
Age Class		3		4		3		4		
Site Class		G	M	G	M	G	M	G	M	Total
LU	Total area of LU (ha)	(ha)	(ha)	(ha)	(ha)	(ha)	(ha)	(ha)	(ha)	(ha)
C1[1]	43 402	210	799	184	1 169	5	17	0	25	2 409
C2	51 838	361	1 017	77	132	0	0	0	3	1 590
C3	31 270	21	29	0	0	0	0	0	0	50
C4	40 978	0	0	0	99	0	0	0	0	99
C5	38 462	0	27	33	123	0	0	0	0	183
C6	47 400	0	16	0	35	0	0	0	0	51
C7	32 745	0	12	0	7	0	0	0	0	19
C8	32 739	1	90	117	392	0	0	0	6	606
C9	35 997	781	847	78	565	0	3	0	0	2 274
C10	35 887	42	225	4	568	0	0	0	0	839
C11	21 442	0	149	1	215	0	0	0	0	365
C12	26 961	51	330	468	2 277	0	7	0	14	3 147
C13	21 023	0	10	0	0	0	6	0	0	16
C14	31 063	60	171	8	261	0	0	0	0	500
C15	41 678	0	105	8	47	0	0	0	10	170
C16	53 522	0	123	0	457	0	0	0	0	580
C17	32 238	0	10	0	6	0	0	0	0	16
C18	71 924	0	90	0	431	0	0	0	0	521
C19	41 214	0	5	0	0	0	0	0	0	5
C20	32 916	0	0	0	104	0	0	2	0	106
C21	44 465	0	72	0	105	0	0	0	0	177
C22	65 801	61	702	0	64	0	0	0	0	827
C23	63 921	88	331	0	129	2	0	0	23	573
C24	70 482	0	12	0	14	0	0	0	49	75
C25	23 380	28	49	44	168	0	30	2	46	367
C26	38 818	126	250	204	245	1	19	0	39	884
C27	55 559	287	403	18	615	3	16	9	33	1 384
C28	48 958	119	291	64	197	167	45	0	29	912
C29	31 669	0	2	0	0	0	0	0	0	2
C30[1]	48 630	158	215	187	702	21	0	0	20	1 303
C31[1]	19 263	36	146	831	1 307	0	14	0	15	2 349
C32	31 258	0	25	87	36	0	5	0	12	165
C33	29 868	1	1	0	2	0	0	0	65	69
C34	42 025	31	84	7	343	29	152	0	407	1 053
C35	20 282	0	0	0	0	0	0	0	0	0
C36	24 108	38	23	8	257	12	182	4	108	632
C37	34 714	0	24	2	341	0	22	0	136	525
Total	1 457 900	2 500	6 685	2 430 (subtotal: 23 028 ha)	11 413	240	518	17 (subtotal: 1 815 ha)	1 040	24 843

Note: 1. Landscape Units selected for more detailed theming at a larger scale and for reconnaissance surveys

The road system is not spatially linked to GIS or inventory databases, so it is not possible to produce a theme map that shows only accessible stands or those that are within a certain distance of a road. Identifying stands that are accessible is a time consuming, manual process requiring local knowledge but is still a critical component in the planning process. This process may produce biased results and may not reflect the actual potential for thinning, however, it is useful in identifying those stands that are economical to thin now.

4.2 Reconnaissance Surveys

4.2.1 Arrow TSA

A total of 25 stands covering approximately 550 hectares were surveyed. The areas were selected based on access and species priority as themed within constrained landscape units. Total mandays expended were 18. Other operational priorities limited the amount of staff time that was devoted to the reconnaissance surveys.

The surveys of the Summit Lake area did not identify any potential commercial thinning stands. However, six potential stands, totalling approximately 109 hectares were selected in the Glade, Stagleap and Erie landscape units for potential commercial thinning.

The main reasons for unacceptability of the surveyed stands included:

- The white pine component identified in the inventory data base was overestimated. In many of the stands, much of the white pine has died or has been logged since the inventory air photo interpretation. In some cases, the current residual volume of white pine was estimated to be marginal. In other cases, the dead and dying Pw had already been salvaged, however, the harvesting operations were not recorded on the maps
- Stand structure and other site conditions were not suitable for commercial thinning.
- Some of the stands were over dense and the potential residual trees had small diameters and small live crowns. These factors indicated a low potential for increased growth after thinning and a high risk for windthrow and snow breakage.
- Extreme variability of stand conditions making merchantability estimates unreliable, and block design difficult and expensive
- Actual stand conditions were different than indicated on the forest cover map
- The age of the stand did not correspond to the age class shown on the map label
- Stands were not adjacent to existing roads or major road construction or improvement was required
- Some areas were too steep for conventional skidding
- Insufficient estimated merchantable volume

There were no detailed and standardized stand selection criteria or a checklist/summary format developed to record the results of reconnaissance surveys as there was for the Cranbrook TSA. Brief summaries of the evaluation were prepared and placed on the inventory polygon file for

each rejected stand in the district office for future reference by staff. ***A standardized reconnaissance summary card and checklist, in conjunction with a route tag, is recommended to ensure that the information is recorded and filed properly. The information could then be placed on an existing file or the District could develop a separate commercial thinning database. Reconnaissance survey information should be retained for both suitable and unsuitable stands.***

The development of standardized biological criteria (e.g.: height/diameter ratios, etc.) and operational factors (e.g.: nature of the understory layers that may impede thinning operations, etc.) and survey format (e.g.: minimum number of cruise plots per stand) would allow the contracting out of this phase of work and ensure sufficient information is collected for accurate inventory reclassification if applicable. Based on the results of the reconnaissance surveys, some suitability criteria for potential candidate stands in Arrow TSA include:

- minimum merchantable volume >160m^3 of which 30-50% could be removed and still maintain an adequately-stocked residual stand
- height/diameter ratio <100 for the dominant and codominant trees
- minimum 30% live crown for the dominant and codominant trees
- slopes <35%
- adjacent to all-weather access road

Stands that clearly did not have commercial thinning potential had the following attributes:

- merchantable volume < 150 m^3/hectare
- residual volume after thinning <50m^3/hectare
- < 25% live crown of dominant and codominant trees
- height/diameter ratio of dominant and codominant trees > 100
- < 600 total stems per hectare in tree layers 1 and 2 (>7.5 cm DBH)
- > 2500 stems per hectare in tree layers 1 and 2
- stand age < 35 years or > 80 years
- basal area <30m^2/hectare
- >10% Armillaria root rot based on above-ground symptoms, especially where there is no possibility of pop-up or pushover thinning techniques due to topography or soils conditions
- more than 500m from current access road or on access road requiring major upgrading

4.2.2 Cranbrook TSA

Evaluation of the theming in LUs C1, C30 and C31 identified 6,061 hectares of potential stands. Approximately 90% of these stands had no existing access and were not considered for reconnaissance surveys (Bill Olsen, pers. comm. 1998). Additional accessible stands were therefore selected from adjacent LUs C2 and C3 for reconnaissance surveys.

Approximately 2,300 hectares, in 44 stands, were surveyed. Of the stands that were surveyed, only 9 met the minimum stand criteria for commercial thinning. The most common reasons for rejection at the reconnaissance survey stage included:

- a combination of low initial merchantable volume, basal area and/or density and/or
- height/diameter ratios of the dominant and codominant trees were greater than 100, which is considered unstable and prone to windthrow and snow damage after thinning

Other reasons included:

- stand ages above minimum harvest age
- slopes greater than 40%, which was the maximum for conventional ground-based harvesting systems
- suitable stand area was too small in area to be considered a viable harvest block
- lack of road access
- moist soils and windthrow concerns

Although the reconnaissance surveys and cruising were done in constrained LUs, it is not known whether the proportions of themed/surveyed/cruised/potentially suitable stands are representative across the TSA or individual LU. The field inventory sampling methodology was biased in favour of accessible stands. Another option to determine local potential for commercial thinning is a more systematic, comprehensive approach to sampling in particular LUs. This approach would include:

1. selection of particular constrained LUs of interest
2. detailed mapping using refined theming criteria
3. development of a sampling plan for themed stands by constraint or resource emphasis, such as visual quality or ungulate winter range
4. sampling the required number of stands regardless of current accessibility

4.3 Cruising

4.3.1 Arrow TSA

A total of 96 hectares, in seven blocks, were cruised and the results are detailed in Table 5. Based on the criteria used for the cruising, the maximum harvest volume available, if all the blocks were thinned, is approximately 10,298 m^3. The weighted average cut volume per block is 107m^3/ha. If only the four of the seven stands with the minimum merchantable volume of 70m^3/ha were thinned, then the potential volume is reduced to 7,949m^3.

The minimum merchantability standard affected the potential commercial thinning volumes. However, the volume increases from lowering the merchantability standard must be viewed with caution because there is a trade-off between increased volume, number of trees to be harvested, wood quality and economics. Using the current minimum merchantability standards

(12.5 cm DBH for lodgepole pine and 17.5 cm DBH for all other species) the stands ranged from 115 m^3/ha - 280 m^3/ha total merchantable volume. The potential volumes that could be removed in the commercial thinning ranged from 46.2 - 183.3 m^3/ha. Based on the minimum economic harvest volume of 70 m^3/ha, only four of the blocks contain sufficient potential thinning volumes. The potential thinning volume from these blocks is 7,949 m^3.

When the minimum merchantability standard was reduced to 7.5 cm DBH for all species, only Block C still showed insufficient volume for commercial thinning. The potential thinning volume from these stands, using the closer utilization standards, increased to 14, 195m^3. The potential merchantable volumes increased on individual blocks from 16% (Block D1) - 125% (Block A) compared to the current merchantability standard. However, the number of trees harvested increased dramatically. For example, to achieve the potential 16% volume gain on Block D1, the number of trees harvested increased by 37%. To achieve the potential 125% volume increase on Block A, the number of trees harvested increased by 711% (Block A).

Additionally, the species composition and quality of the smaller diameter trees were considerably different than that of the larger trees that are harvested. The larger, overstory trees in these stands are predominantly lodgepole pine, larch and Douglas-fir. The smaller trees that make up the additional volume at the lower utilization standards are spruce, hemlock, cedar and lodgepole pine. The shade tolerant trees are limby with long live crowns and a high percentage of juvenile wood. The understory lodgepole pine often had high height/diameter with considerable sweep due to snow loading. All these factors result in a higher proportion of less-preferred species with low quality wood.

There are other economic issues with lowering the current merchantability limits. The Kootenay super-utilization study (FRBC 1996) indicated the following trends:

- Recoverable volumes are lower and range from 20-75%. The recovery increased with diameter class
- Often specialized logging, loading and hauling equipment is needed to handle the large amount of extra, small material
- Where small wood is mixed with larger material, breakage during falling can be high, especially on steep slopes
- More complicated handling of logs in the landing

Although one residual basal area (RBA) target simplified the cruising procedure, it was not always sufficient, by itself, to provide enough guidance for potential volume removal or to develop suitable residual stand structures. Using the current minimum merchantability standards, RBAs ranged from 7.2m^2/ha - 14.7m^2/ha. The target RBA was achieved on all the blocks except Block A and D2. However, the target residual densities were not met on any block. Residual densities ranged from 165 - 304 trees per hectare. The target residual densities were not achieved even when the minimum merchantability standard was lowered to 7.5 cm

Table 5. Results of commercial thinning cruising in Arrow TSA[1].

Block	Size (ha)	Minimum Merchantable DBH (cm)	Cut Trees				Residual Trees				Total Trees		
			Number of Trees Harvested (Trees/ha)	Volume Harvested (m^3/ha)	Basal Area Harvested (m^2/ha)	% Basal Area Harvested	Residual Density (Trees/ha)	Residual Volume (m^3/ha)	Residual Basal Area (m^2/ha)	% Residual Basal Area	Density (Trees/ha)	Merchantable Volume (m^3/ha)	Basal Area (m^2/ha)
A	23.0	Pl - 12.5, Others- 17.5	192	59.4	7.5	51.0	229	55.6	7.2	49.0	421	115	14.7
		All Species - 7.5	1558	134	23.9	68.1	462	76.1	11.2	31.9	2020	210.1	35.1
B1	10.0	Pl - 12.5, Others- 17.5	309	89.8	12.6	55.3	197	80.1	10.2	44.7	506	169.9	22.8
		All Species - 7.5	495	114.7	15.6	58.4	249	88.8	11.1	41.6	743	203.5	26.7
B2	8.0	Pl - 12.5, Others- 17.5	178	65.1	9.0	46.9	165	83.3	10.2	53.1	343	148.4	19.2
		All Species - 7.5	250	79.0	10.9	50.1	185	87.0	10.5	49.9	435	166.0	21.4
C	10.0	Pl - 12.5, Others- 17.5	167	46.2	6.9	40.4	221	75.7	10.2	59.6	387	122.0	17.1
		All Species - 7.5	300	64.1	9.3	45.6	261	84.9	11.1	54.4	561	148.9	20.4
D1	16.0	Pl - 12.5, Others- 17.5	480	160.7	24.4	62.6	304	102.7	14.7	37.4	784	263.4	39.0
		All Species - 7.5	658	186.9	27.8	64.4	362	110.8	15.4	35.6	1020	297.7	43.2
D2	25.0	Pl - 12.5, Others- 17.5	434	149.9	22.6	70.6	225	60.5	9.4	29.4	659	210.3	32
		All Species - 7.5	870	190.9	29.6	73.3	299	71.7	10.8	26.7	1169	262.6	40.4
D3	4.0	Pl - 12.5, Others- 17.5	450	183.3	27.5	68.8	235	96.7	12.5	31.2	685	280.0	40
		All Species - 7.5	847	232.8	33.8	73.0	235	100.4	12.5	27	1082	333.2	46.3
Total	96 ha	Pl - 12.5, Others- 17.5	Total merchantable volume 17,343.1 m^3 Average merchantable volume/ha 180.7m^3 Total potential cut volume 10,298 m^3 Weighted average cut volume 107 m^3/ha										
		All Species - 7.5	Total merchantable volume 22,345.3 m^3 Average merchantable volume/ha 232.7m^3 Total potential cut volume 14,195 m^3 Weighted average cut volume 147 m^3/ha										

Note: 1. Figures do not include dead potential volume.

DBH for all species. The main reasons for not achieving the target residual densities include:

- Current density in tree layer 1 was less than the target in four of the blocks. When the layer 2 trees are included, the current density was still below the target density in two blocks.
- Insufficient layer 1 and 2 trees that met the minimum biological and health standards for residual trees (e.g.: height/diameter ratio < 100, % live crown, etc.) resulting in a higher number of them being selected for cutting.
- Primary consideration for selection of leave trees was residual basal area, not density, or a combination of these factors

Additionally, the understory, shade-tolerant species have the capacity for improved growth after the thinning. From both a biological and economic perspective, it may be more appropriate to retain more of the smaller trees for the final harvest, provide additional stand structure after the thinning and remove more volume from the larger tree sizes.

The RBA selected for determining the potential cut volume in this cruise exceeded the current guidelines of the Resource Emphasis Areas for partial cutting. Therefore, if the stands were logged to the cruise specifications and current guidelines, they would not contribute their full potential to mitigate the constraints to clearcutting. Resource Emphasis Areas allow different maximum levels of basal area removals to meet their specific management objectives (Table 6). For all of the blocks, the predominant REA was domestic watersheds. Additionally, portions of Blocks C and D1 contained a predominant REA of visual quality objective-partial retention. If these blocks were harvested based on the target RBA in the cruise, all would contribute to the clearcut landbase. Blocks A, B1, B2, and C would contribute at a rate of 50% ECA. For example, every two hectares thinned would be equivalent to one hectare of clearcutting. Blocks D1, D2 and D3 would contribute at a rate of 100% ECA - every hectare thinned would equal one hectare of clearcutting.

The REA designations for the blocks were not known prior to the cruise phase. The target RBA and cut/leave tree characteristics were based on professional experience to provide a reasonably stocked and healthy stand after thinning. If the REA had been known prior to the cruise, the target RBA could have been adjusted, in some cases, to reflect the maximum allowed by the REA guidelines. Based on the results in Table 5, only Blocks D1, D2 and D3 appear to have sufficient merchantable volume to allow both REA guidelines and minimum economic harvest levels to be met.

REA partial cutting guidelines were developed for mature stands and they should be reviewed for their applicability in commercial thinning. If applied to immature stands, they represent significant constraints to a potential commercial thinning program from both biological and economic standpoints. The guidelines should be reviewed for the following reasons:

1. The commercial thinning prescription may not be able to fully address the forest health or the most appropriate residual stand conditions. To accommodate REA guidelines, diseased, damaged, poorly-formed or unstable trees may be left after the thinning resulting in a less healthy, vigorous or higher risk stand.

2. Target mature stand structures for such management objectives as caribou habitat and ungulate winter range, can be created through carefully developed silviculture stand management activities such as juvenile spacing and commercial thinning.

3. The guidelines reduce the number of potential stands suitable for commercial thinning. For example, in a watershed REA, the minimum merchantable volume of the stand must be at least 233m^3/ha in order to be able to extract a minimum 70m^3/ha and still remain within the maximum allowable 30% harvest. In a VQO - retention REA, the minimum merchantable volume must be 350m3/ha to achieve a maximum allowable 20% harvest.

4. Stands have to be harvested at older ages than are currently considered suitable and planned for commercial thinning. Few natural stands in the age range between 40 - 80 years have sufficient merchantable volumes to meet minimum economic requirements and still achieve the REA guidelines. This would negate the potential benefits of commercial thinning both from a harvest flexibility and stand response perspective. Minimum harvest ages in the recent TSR were 70 years for lodgepole pine and 80 years for Douglas-fir/larch types. Once the stands reach the minimum harvest age, they become part of the pool of stands that may be suitable for other partial cutting or clearcutting management options and are not considered for commercial thinning. Additionally, as stands get older, the ability of residual trees to improve their growth after thinning decreases.

5. If the maximum REA guideline is exceeded in order to be economically viable, the thinning does not achieve either the REA objective for partial cutting or the economic efficiencies and increased volume per hectare associated with clearcutting.

6. Many of the age class III and IV stands have been previously partially cut or juvenile spaced in the 1980's under various government make-work programs (Arnie Erickson, pers. comm. 1998). Some merchantable species or diameter classes were harvested independently, at some unknown time, or in conjunction with white pine salvage programs. The applicability of the current guidelines in relation to current and planned stand structures must be reviewed.

Based on these results, cruising criteria can and should be refined to ensure that management objectives are satisfied and a better estimate of the thinning potential at the stand level is obtained. Some of these criteria include:

- The maximum RBA for partial cutting to meet the Resource Emphasis Area objectives should be identified prior to cruising

Table 6. Resource Emphasis Area hierarchy and maximum partial cutting guidelines allowed without violating clearcutting constraints.

Resource Emphasis Area (REA)	Hierarchical Priority Ranking	Constraints to Clearcutting within the KBLUP	Maximum Basal Area Removal Before Harvesting is Considered Equivalent to Clearcutting (%)	Minimum Residual Basal Area to meet REA Guideline (%)
Caribou Habitat	1	Most constraining ⇓	•25% in single-storied stands •34% in multi-storied stands with a minimum $20m^2$ residual basal area •30% of the stand volume if using group selection system	•75 •66 •70
VQO Retention	2	⇓	20	80
VQO Partial Retention	3	⇓	50	50
Community Watershed	4	⇓	40	60
Domestic Watershed	5	⇓	•<30: no effect on ECA •30-60: 50% ECA •60+: 100% ECA	•>70 •40-70 •<40
Ungulate Winter Range	6	⇓	15-70% retention of mature forest cover depending on ungulate species, BEC subzone, slope and distance from grassland	30-85
Integrated Resource Management	7	Least constraining	60	40

Notes: 1. These REAs are hierarchical and were developed by the Ministry of Forests and Ministry of Environment, Lands and Parks for the KBLUP.

2. ECA: The equivalent clearcut area (ECA) is defined as the area that has been clearcut, with a reduction factor to account for the hydrological recovery due to forest regeneration. Maximum ECA limits are calculated at the watershed or landscape unit level of planning. Individual cutblocks may exceed the ECA guidelines as long as the average ECA for all the cutblocks does not exceed the maximum limits (MoF 1995)

- Cut/leave tree criteria should be refined and include factors such as species, size, shade tolerance, etc. should be included (e.g.: all healthy spruce <17.5 cm DBH designated as leave tree; all lodgepole pine between 7.5 and 12.5 cm DBH designated as cut trees, etc.)

- Residual densities can be estimated at each plot or summarized for all plots, to determine if target residual densities are being achieved based on cut/leave tree selection. Densities can be determined using either fixed or variable radius plots for specific species and/diameter classes or aggregated.

  For variable radius cruise plots, the standard formula for determining residual density is:

  $$\mathbf{RD = Trees \times BAF \div [\pi \times (Diameter \div 200)^2] \div number\ of\ plots}$$

  Where: RD = Residual Density (trees per hectare)
  Trees = Number of trees counted
  BAF = Basal Area Factor of the prism
  π = 3.1416
  Diameter = Average diameter (cm) of the leave trees
  (Peter Semenoff, Regional Cruising Co-ordinator, pers. comm. 1998)

Cruise summaries provide useful information that can be easily incorporated into the regional prototype EXCEL database program for analysing "what if..." partial cutting scenarios. Regional management should support the further development of the regional EXCEL program for commercial thinning and partial cutting planning. Regional Revenue section has developed a prototype program using the EXCEL database management program (Peter Semenoff, pers. comm. 1998). The prototype program allows the user to input pertinent cruise data and analyse the results of various management options. For example, the user can vary the percent RBA or volume removal by species and/or diameter class. From the results, the user can determine which combinations best satisfy management or economic objectives while still maintaining the most appropriate biological stand structure. Results of initial testing of the prototype by Arrow and Cranbrook district staff are encouraging and positive (Arnie Erickson, Bill Olsen pers. comm. 1998)

4.3.2 Cranbrook TSA

Eight stands, totalling approximately 273 hectares, were cruised. The results are shown in Table 7. Using the current standards, the total merchantable volumes ranged from 83.2 to 306.0m^3 per hectare with a weighted average of 197.8m^3 per hectare. One strata (Block 1b) was recommend for clearcutting because of the stand structure and all but one of the other blocks (Block 7) showed sufficient potential volume available for commercial thinning. The total potential thinning volume from these stands was 32,650 m^3.

When the merchantability standards were reduced to 7.5cm DBH for all species, the merchantable volume increased from 7.0 - 51.3% (Block 4 and Block 6 respectively) and all the

blocks showed sufficient volume for commercial thinning. The total potential thinning volume from these stands at the closer utilization levels was 41,704m^3.

As in the Arrow TSA, the increase in harvest volume from lowering the merchantability standard resulted in an increase in the number of trees that must be harvested. For example, in Block 1a, to achieve a 20m^3, or 25% increase in volume, the number of trees required to be harvested increased by 121%. For Block 6, a doubling of volume comes at the expense of handling approximately three times the number of trees.

All of the blocks were within either the ungulate winter range (Blocks 1a, 1b, 4, 5, 6) or integrated resource management (Blocks 2, 3, 7, 8) REA. All of the ungulate winter range blocks were within the MSdk BEC subzone, for which the guidelines allow from 30-40% minimum mature forest cover. Assuming these trees qualify as mature forest cover, if the potential volumes specified in Table 7 were harvested, none of the blocks would meet the ungulate winter range guidelines for partial cutting. Of the blocks within the integrated resource management REA, only Blocks 3 and 8 would meet the guidelines. However, for these two blocks, the maximum allowable removal was not achieved. An additional 2.6% and 5% respectively more basal area could be removed (approximately 858m^3 of volume) before the guideline maximum is achieved. ***Therefore knowing the REA guidelines before specifying the cruise or harvest parameters allows both management guidelines to be met and maximum volume removal.***

Commercial thinning is a suitable harvesting system that can be used where clearcutting is constrained by REA guidelines, but there is a volume trade-off between meeting REA guidelines, maximizing partial cutting volume removal, maximizing stand productivity and maintaining a healthy residual stand. The effects of different levels of thinning on productivity and REA objectives should be determined using stand level growth models such as TASS and PrognosisBC. From the results in Table 7, there is sufficient merchantable volume available in all the stands, except Blocks 1b and 6, to allow the REA guidelines for partial cutting to be met while harvesting at least the minimum economic volumes. The effects on stand productivity of removing either the specified volumes as per the cruise (Table 7), the maximum allowed by the REA guidelines or the minimum required to be economically viable were not examined. However, Johnstone (1997) and Robinson et al. (1996) report that stand productivity, measured as MAI (mean annual increment), can be affected by management practices such as timing of first harvest entry, residual basal area after the harvest, years to final harvest. Robinson et al. (1996) also show the impacts of partial cutting and different levels of *Armillaria* root rot on productivity. These studies indicate that there are certain combinations of partial cutting practices that can slightly increase or maintain productivity levels close to those using clearcutting systems. There are also certain combinations of management practices that can greatly reduce productivity.

Even after the reconnaissance surveys and cruising, a field inspection of potential stands by qualified District staff was still required to ensure the suitability of the stands for thinning. A field inspection was done on Blocks 5, 6 and 7 by District management and operational staff and this author after the cruise compilation reports had been reviewed. Only Block 6 was still

Table 7. Results of commercial thinning cruising in Cranbrook TSA[1].

Block	Size (ha)	Minimum Merchantable DBH (cm)	Cut Trees				Residual Trees				Total Trees		
			Number of Trees Harvested (Trees/ha)	Volume Harvested (m^3/ha)	Basal Area Harvested (m^2/ha)	Basal Area Harvested (%)	Residual Density (Trees/ha)	Residual Volume (m^3/ha)	Residual Basal Area (m^2/ha)	Residual Basal Area (%)	Density (Trees/ ha)	Merchantable Volume (m^3/ha)	Basal Area (m^2/ha)
1a[2]	28.7	Pl - 12.5, Others- 17.5	267	80.0	10.0	45.2	169	102.3	12.1	54.8	436	182.5	22.1
		All Species - 7.5	591	100.0	12.9	50.0	226	107.7	12.9	50.0	817	208.7	25.8
1b[2]	4.1	Pl - 12.5, Others- 17.5	[3]121	83.2	10.0	100	[3]0	0	0	0	121	83.2	10.0
		All Species - 7.5	[3]121	84.5	10.0	100	[3]0	0	0	0	121	84.5	10.0
2	29.5	Pl - 12.5, Others- 17.5	732	185.4	23.5	62.3	218	70.9	9.0	27.7	950	256.3	32.5
		All Species - 7.5	1284	233.6	29.5	74.7	340	77.7	10.0	25.3	1624	311.2	39.5
3	26.4	Pl - 12.5, Others- 17.5	677	127.0	17.9	57.4	359	107.6	13.3	42.6	1036	234.6	31.2
		All Species - 7.5	859	149.8	19.6	56.6	474	119.9	15.0	43.4	1333	269.7	34.6
4	34.0	Pl - 12.5, Others- 17.5	555	199.5	22.7	68.2	166	106.5	10.6	31.8	721	306.0	33.3
		All Species - 7.5	651	212.9	23.5	76.2	292	114.5	12.0	33.8	942	327.4	35.5
5	17.3	Pl - 12.5, Others- 17.5	653	191.1	26.2	72.8	212	81.0	9.8	27.2	865	272.1	36.0
		All Species - 7.5	785	210.2	26.5	54.0	1003	146.4	22.6	46.0	1788	356.6	49.1
6	41.9	Pl - 12.5, Others- 17.5	339	58.1	9.5	48.0	250	70.0	10.3	52.0	589	128.0	19.8
		All Species - 7.5	1354	117.0	19.2	63.8	318	76.6	10.9	36.2	1671	193.6	30.1
7	42.3	Pl - 12.5, Others- 17.5	473	116.5	16.1	68.5	140	55.2	7.4	31.5	613	171.6	23.5
		All Species - 7.5	745	142.0	19.6	64.7	455	73.0	10.7	35.3	1200	215.0	30.3
8	49.4	Pl - 12.5, Others- 17.5	350	75.7	11.6	55.0	206	67.2	9.5	45.0	556	142.9	21.1
		All Species - 7.5	668	98.8	15.3	60.2	248	72.5	10.1	39.8	916	171.3	25.4
Total	273.6 ha	Pl - 12.5, Others- 17.5	Total merch. volume 54,125.7 m^3		Average merch. volume/ha 197.8m^3		Total potential cut volume 32,650 m^3				Weighted average cut volume 119.3 m^3/ha		
		All Species - 7.5	Total merch. volume 65,606.0 m^3		Average merch. volume/ha 239.8m^3		Total potential cut volume 41,704 m^3				Weighted average cut volume 152.4 m^3/ha		

Notes: 1. Figures do not include dead potential volume.
2. Blocks 1a and 1b are different strata within the same block.
3. Stand conditions not suitable for commercial thinning, consultant recommended clearcutting.

considered suitable for commercial thinning based on the collective experience of the staff. The other blocks were considered a high risk from residual stand structure and forest health perspectives. This is because the cruisers had selected the "best" dominant trees as residual trees for the purposes of the cruise. However, many of the "best" dominant trees had a high incidence of mechanical damage or dwarf mistletoe disease (*Arceuthobium* spp.) If these dominant, damaged or diseased trees were harvested, a large component of the residual stand would be slower-growing, codominant or understory lodgepole pine which are susceptible to mountain pine beetle attack (Tom Hedin, Bill Olsen pers. comm. 1998). These results are similar to field inspections of cruised stands in the Arrow District. In Arrow District, although four of the seven cruised stands (stands A, B1, B2 and C) were considered suitable for thinning, however, 30-40 percent of the area in these stands is expected to be excluded from thinning (Arnie Erikson pers. comm. 1998).

4.4 Wood Supply Modelling

4.4.1 Arrow TSA

The effects of commercial thinning on wood supply were modelled by Timberline Forest Inventory Consultants Ltd., and the results are presented in Table 8. Because of the assumptions, methodology and the prototype FSSIM model used, the clearcutting base case results differ from TSR wood flow so the effects of commercial thinning should only be viewed comparatively. Additionally, the KBLUP and TSR wood supply analysis require a maximum 10% reduction in wood flow per decade. For strictly comparative purposes, the effects of various levels of commercial thinning with no wood flow constraints are presented as well.

Arrow TSA is highly constrained for clearcutting because of visual quality objectives, community and domestic watersheds. However, the effects of the constraints vary over time because of harvest practices and the changing forest structure, so the first decade effects may be different than the effects in future decades.

When there were no wood flow constraints applied to the modelling scenarios, commercial thinning was shown to increase wood availability in the first decade from 3 - 10% and from 1 - 4% over the first four decades (Wang and Pollack 1998).

When wood flow constraints were applied to the analysis, commercial thinning increased the wood availability in the first decade from 2 - 5%. This increase is not additive to the increase from other partial cutting practices in constrained areas, because, operationally, a stand will either be a candidate for commercial thinning or some other partial cutting practice. The thinning program could not be sustained above 400 hectares per year because, by decade 6, there are fewer candidate stands. The Enhanced Forest Management Pilot Project (EMFPP) in Invermere also showed that, in second growth stands, unless incremental silviculture activities such as juvenile spacing, pruning or fertilization are conducted, then sufficient operable commercial thinning types will not be created in the future. There is, however, a threshold level of spending on incremental silviculture spending beyond which there is a diminishing effect on wood supply (Messmer and White 1998). ***Therefore Districts should analyze their current***

second growth stand structures and develop appropriate stand management regimes and suitably-sized stand tending programs to allow sufficient future partial cutting and commercial thinning options to minimize future wood flow shortages.

From additional sensitivity analysis, partial cutting was most effective when focused on the REAs, such as VQOs, where the constraints are prohibiting stands from being clearcut harvested. This confirms another analysis in which the Arrow TSA timber supply was identified as being sensitive to other factors such as green-up and cover constraints as well as a reduction of the minimum harvest age. Partial cutting or commercial thinning was considered to be able to address these issues but opportunities were limited by terrain, species suitability and root rot (MoF 1997). Commercial thinning was also found to increase mid-term (decades 2-6 in the future) wood supply by 5-11% in the adjacent Kootenay Lake TSA, which is also highly constrained to clearcutting (MoF 1997). In a less constrained TSA, such as Invermere, focusing commercial thinning and partial cutting only in limited areas with VQO constraints showed insufficient volumes to offset wood flow declines (Messmer and White 1998). Visual quality objectives alone were insufficient to define partial cutting opportunities and their effects on wood flow. Therefore the partial harvesting opportunities must be defined more precisely by also taking into account both economic operability and stand conditions.

There appears to be an optimum balance between clearcutting and partial cutting systems that maximizes wood flow, but it varies with landscape unit, silviculture and management constraints such as mature biodiversity and hydrological green-up. Any stand, site, or administrative factors that allow partial harvesting to be economically viable at lower minimum volume removals, greatly increases the impact in Decade 1 wood supply (Wang and Pollack 1998).

Partial cutting is already being practised in some constrained REAs. Therefore, some of the wood supply increases attributed to the use of partial cutting in this study may already be realized. Partial cutting systems were used on 25% of the total area harvested from 1992 and 1996. Partial cutting accounted for 48% of the harvested area in the VQO-partial retention REA, 35% in the community watershed REA, 10% in the integrated resource management REA and 5% in the domestic watershed REA. The general trend, however, has been a decrease in the amount of partial cutting from the beginning to the end of the 5-year period. There appears to be potential to increase the amount of partial cutting in some landscape units and resource emphasis areas (Listar *et al.* 1998).

Table 8. Effects of various levels of commercial thinning on wood flow in the Arrow TSA. Non-recoverable losses are not included. Adapted from Wang and Pollack (1998).

Harvesting regime	Commercial thinning regime (ha/yr)	Maximum annual harvest with no wood flow constraints (x 1000m^3/yr)	Difference from clearcut base case (%)	Maximum wood availability with no wood flow constraints (x 1000m^3)	Difference from clearcut base case (%)	Maximum annual harvest with wood flow constraints (x 1000m^3/yr)	Difference from clearcut base case (%)
		Decade 1		Decades 1-4		Decade 1	
Clearcut base case	0	7,664	n/a	22,130	n/a	620	n/a
Commercial thin	200	7,916	3%	22,448	1%	630	2%
Commercial thin	300	8,050	5%	22,562	2%	640	3%
Commercial thin	400	8,185	7%	22,963	4%	640	3%
Commercial thin	500	8,318	9%	22,994	4%	650	5%
Commercial thin	600	8,452	10%	23,089	4%	650	5%

4.4.2 Cranbrook TSA

The Cranbrook TSA is not as constrained to clearcutting as Arrow TSA based on initial sensitivity analysis. Although commercial thinning was not specifically modelled, the effects of partial cutting in relation to wood flow and the KBLUP was completed for Cranbrook TSA. Partial cutting, even when employed in constraining REAs, did not affect first decade wood supply. It was thought that commercial thinning also would show the same minimal impacts (Wang and Pollack, 1998).

In the last TSR, approximately 40% of the forests in the Cranbrook TSA were 30-80 years of age. A lowering of the minimum harvest age did have an impact on mid-term wood supply. ***Considering the age class distribution and potential sensitivity to minimum harvest age, additional analysis of the effects of commercial thinning on wood flow may be warranted, however , a different approach may need to be developed.***

5. RECOMMENDED PROCESS FOR SIMILAR PROJECTS

The process used in this study identified and addressed many key issues involved in developing a commercial thinning program. However, based on the experienced gained from this study, there is potential to refine the process and methodology in future projects, and other management units, using locally-developed selection criteria.

The process involves the following phases:

1. Identifying the need or potential for a commercial thinning program is the first phase of the process. This involves discussions with local SBFEP and Licensee staff to determine if there is an interest and a market for products available from younger stands. Additional analysis of Timber Supply Reviews, the Kootenay-Boundary Land Use Plan, and other plans, similar to the process used in Vancouver Region (Anonymous 1998), can provide strategic direction to a commercial thinning program through alleviating wood flow problems, increasing harvesting flexibility, alleviating age class distribution gaps or addressing other management objectives

2. Once the value of a commercial thinning program has been identified, specific biological, operational and economic criteria are developed, in conjunction with Licensees, to identify potential stands. These criteria are then used during later phases of the project.

3. Geographic information system theme mapping then identifies potential stands across the management unit. Both inventory and KBLUP databases should be used in the theming. The inventory FIP files include both broad biological (e.g.: timber type, age, site class, etc.) and operational (e.g.: percent slope, etc.) factors. The KBLUP files contain landscape unit, resource emphasis area information. Final theming results should then identify potential hectares by landscape unit, resource emphasis area, across the management unit.

4. The next step in the process is to identify where the commercial thinning will be concentrated. In order to have a mitigation effect on AAC, the thinning must be done strategically. Therefore, landscape units and resource emphasis areas that are the most constrained to clearcutting should be identified and targeted for further analysis. These landscape units are identified by reviewing TSR and KBLUP constraint reports in conjunction with the theming results.

   If these constrained areas do not identify sufficient potential area, there are two alternatives to consider. The first is to re-theme using more refined criteria. The second alternative is less strategic, but may identify additional, more easily accessible thinning potential. It involves selecting landscape units that are less constrained but adjacent to the constrained units, those with the most potential hectares or those closest to existing mill facilities.

5. Once the potential areas, landscape units and resource emphasis areas are identified, a statistically sound sampling plan must be developed. The sampling plan must include both accessible and inaccessible stands. This will allow future reconnaissance survey and cruising results to be extrapolated to similar stand types in other landscape units or across the management unit. Ministry of Forests Research Branch should be contacted to assist in the development of any statistically sound sampling plans.

6. Reconnaissance surveys are then conducted in the stands selected for sampling. This is a key phase which identifies stands that definitely do not meet minimum thinning suitability criteria identified in phase 2 above. Suitability criteria must be easily identified or quantified in the field.

   Because the results of the reconnaissance surveys have enormous impacts on the cost and success of future phases, it is recommended that only experienced consultants or District staff conduct this phase. If these surveys are contracted, it is recommended that District staff accompany the surveyors on at least the first day of surveying to ensure that the objectives of the surveys are met. This also allows suitability criteria to be refined, if required, based on actual stand conditions.

7. Stands that meet the minimum suitability criteria are then cruised. Potential thinning volume and residual stand structure are identified during this phase. To ensure that all the potential thinning volume is identified for sawlogs, pulp and special products, it is recommended that all species be cruised to a minimum 7.5 cm. DBH (diameter at breast height).

   To meet strategic objectives, minimum and maximum thinning volumes must be identified in advance. The minimum economic thinning volumes are identified by Licensees in phase 2 above. The maximum thinning volumes are identified from specific management constraints (e.g.: Forest Practices Code adjacency guidelines, KBLUP domestic watershed guidelines for partial cutting, etc.).

   Residual stand structure should be identified by selecting the appropriate combination of cut and leave trees to best meet the management objectives while providing sufficient thinning volumes. The cut and leave trees are based on biological, forest health, and economic criteria as well as management guidelines. The cut and leave tree specifications should also identify most of the important biological and forest health criteria (Appendix B and C). However, additional economic criteria by diameter class for understory or less desirable tree species (e.g.: immature spruce less than 12.5 cm DBH, etc.) should be identified for future projects.

   Cruising for commercial thinning requires not only additional information to be collected but also involves applying management constraints and professional judgement in the selection of cut and leave trees. Therefore, as with the

reconnaissance surveys, only experienced cruisers are recommended for this phase and District staff should accompany contractors on at least the first day of cruising. Ideally, the same crew that conducted the reconnaissance surveys should also conduct the cruise as part of a two-phase reconnaissance survey/cruising contract.

Additional stand information should be collected during the cruise (if there is sufficient funding) to allow the current and target stand conditions to be modelled using Prognosis^{BC}. This modelling will determine if the thinning regime will produce negative impacts on stand productivity.

The use of prisms is preferred to fixed-radius plots is recommended for this phase. Prisms allow a more direct comparison in the field between proposed cut/residual basal area based on actual stand conditions and residual basal area requirements to meet specific management objectives such as visual quality. Specific strength prisms can be used to ensure that certain diameter classes are not over sampled whereas fixed radius plots tend to over sample the smaller diameter trees and under sample larger diameter trees (Peter Semenoff, pers. comm. 1998). Individual trees selected as residuals, in each cruise plot, should be clearly marked in the field to assist in future check cruising and refining cut/leave criteria.

8. After reviewing cruising reports, District staff should at least walk through all the potential thinning stands to confirm cruising results, identify the actual stands to be thinned, and "fine tune" preliminary stand boundaries, volume estimates and prescriptions.

   Prior to initiating silviculture prescriptions, stand layout and actual thinning sales, it is recommended that Licensees view the selected stands. This allows District staff an opportunity to gauge the potential to sell the thinning products and volume. It also allows fine tuning of the thinning suitability, reconnaissance survey and cruising criteria developed earlier.

9. As commercial thinning opportunities are driven by demand for special products, favourable economics and continuity of wood supply, it is recommended that a pool of thinning stands are layed out and ready for sale when the market conditions are suitable. This will allow Districts and Licensees to take immediate advantage of the opportunity to harvest the smaller timber or specialty products.

6. SUMMARY AND RECOMMENDATIONS

A methodology for identifying commercial thinning opportunities was tested and refined. Operationally feasible stands were identified on the ground in both the Arrow and Cranbrook TSAs and positive effects of commercial thinning on wood flow in Arrow TSA were demonstrated.

In Arrow TSA, approximately 44,557 hectares were identified through GIS theming. Reconnaissance surveys were conducted on a sample of 550 hectares of themed stands. Of the surveyed stands, 96 hectares were considered potentially suitable and were cruised. The cruising identified between 10,298 and 14,195 m^3 of potential thinning volume depending on minimum utilization standards. Different levels of commercial thinning were modelled and a potential 2-5% increase in short term wood supply was identified when the thinning was concentrated in constrained Resource Emphasis Areas. The positive effect of the thinning program peaked at 400 hectares per year because, by decade 6, there are limited candidate stands. This increase in wood flow due to commercial thinning is not additive to the increase from other partial cutting practices in constrained areas. As partial cutting is already being practised in some constrained REAs, some of the wood supply increases attributed to the use of commercial thinning in this study may already be realized.

In the Cranbrook TSA, 24,843 hectares were identified through theming. Reconnaissance surveys on a sample of approximately 2,300 of these themed stands identified 274 hectares that may be suitable for thinning. This area was cruised and a potential 32,650 and 41,704 m^3 of thinning volume was identified depending on minimum utilization standards.

The main issues affecting the development of a commercial thinning program, identified in this study, were 1) road access, 2) stand suitability, 3) utilization levels and 4) management guidelines for non-timber resources. Other economic and administration issues are recognized, but were not investigated.

Regardless of the theming criteria used, approximately 90-95% of the themed stands were not accessible without new roads or road up-grades and were automatically eliminated from further examination for thinning potential. Additionally, the road systems are not spatially linked to GIS or inventory databases, so it is not possible to produce a theme map that shows only accessible stands or those that are within a certain distance of a road. In the short-term, two approaches are recommended to deal with the access issue. The first approach is to review current plans to determine where new access is planned or existing access adversely affected. The second approach involves relaxing the current access criteria and accept higher road building costs to some potential stands.

Inventory FIP files and GIS databases can be used to better identify potential stands, filter out unsuitable stands and reduce the number of reconnaissance surveys. The theming is useful for identifying general stand characteristics and management

designations but has poor predictive capability in identifying actual critical stand structural and health conditions. Despite these limitations, theming is a critical planning phase and re-theming, using more refined criteria, is recommended for both TSAs.

Approximately 80-90% of themed stands were eliminated at the reconnaissance survey stage, mainly due to biologically unsuitable structures of the unmanaged stands or forest health concerns. Both of these factors affect the potential thinning volume and residual stand growth. After theming and access, the reconnaissance survey phase has the highest potential to either identify or eliminate the largest number of potential candidate stands. Although the reconnaissance surveys were concentrated in constrained LUs, the methodology did not allow the identification of the entire population of potential stands in any LU or if the sampled population was representative of the majority of the stands. In the long-term, a more systematic approach to sampling is recommended.

At the cruising stage, approximately 60% of the stands are eliminated mainly due to insufficient volumes, inappropriate stand structure and forest health concerns. The minimum merchantability standard affected the potential thinning volumes. However, the volume increases from lowering the merchantability standard must be viewed with caution because there is a trade-off between increased volume, number of trees to be harvested, wood quality and economics.

Identifying the REA guidelines or constraints before specifying the cruise or harvest parameters is critical. There are harvest volume and economic trade-offs between meeting REA guidelines, maximizing partial cutting volume removal, maximizing stand productivity and maintaining a healthy residual stand. Stand level growth models such as TASS or Prognosis^{BC} should also be used to identify high yield silviculture prescriptions that maximize stand growth and still meet REA objectives.

At the forest level, there appears to be an optimum balance between clearcutting and partial cutting systems that maximizes wood flow, but it varies with landscape unit, silviculture and management constraints. Both the timing and location of the partial cutting is critical, and if it is not targeted in the most constraining landscape units and REAs, the positive impacts on wood flow will not be achieved.

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APPENDIX A

Commercial thinning questionnaire sent to Licensees

PRELIMINARY STAND SELECTION GUIDELINES
FOR COMMERCIAL THINNING

The basic principle we want to follow when selecting suitable stands for commercial thinning is that the identified stands will respond silviculturally to the thinning. We must recognize that a lot of the unmanaged stands have "missed the boat" and will not respond to thinning.

1.General inventory/biological considerations

-Density range _____ sph

-Height/diameter ratios for residual trees e.g.:≤100/<90 for PL

-% live crown of residual crop trees e.g.:≥30%

-Last 10 years growth - have the residual crop trees stopped growing? _____

Other

2. Site Productivity

-Site index e.g.: minimum 18m @ 50 years breast height age (?)

3. Merchantability

These merchantability limits are based on current milling capability, technology and prices. These are my estimates only for discussion purposes. Please modify to meet your actual requirements.

sawlog:	-minimum dbh	_____ cm
	-minimum top diameter	_____ cm
	-minimum log length	_____ m
	-minimum volume per hectare	_____ m^3/ha
	-minimum basal area per hectare	_____ m^2/ha
	-maximum logging cost to roadside	_____ $/$m^3$
pulpwood:	-minimum dbh	_____ cm
	-minimum top diameter	_____ cm
	-minimum log length	_____ m
	-minimum volume per hectare	_____ m^3/ha
	-minimum basal area per hectare	_____ m^2/ha
	-maximum logging cost to roadside	_____ $/$m^3$

These merchantability limits are based on current milling capability, technology and sawlog prices increasing.

sawlog:	-minimum dbh	_____ cm
	-minimum top diameter	_____ cm
	-minimum log length	_____ m
	-minimum volume per hectare	_____ m^3/ha
	-minimum basal area per hectare	_____ m^2/ha
	-maximum logging cost to roadside	_____ $/$m^3$
pulpwood:	-minimum dbh	_____ cm
	-minimum top diameter	_____ cm
	-minimum log length	_____ m
	-minimum volume per hectare	_____ m^3/ha
	-minimum basal area per hectare	_____ m^2/ha
	-maximum logging cost to roadside	_____ $/$m^3$

These merchantability limits are based on current milling capability, technology and pulpwood prices increasing.

sawlog:	-minimum dbh	_____ cm
	-minimum top diameter	_____ cm
	-minimum log length	_____ m
	-minimum volume per hectare	_____ m^3/ha
	-minimum basal area per hectare	_____ m^2/ha
	-maximum logging cost to roadside	_____ $/$m^3$
pulpwood:	-minimum dbh	_____ cm
	-minimum top diameter	_____ cm
	-minimum log length	_____ m
	-minimum volume per hectare	_____ m^3/ha
	-minimum basal area per hectare	_____ m^2/ha
	-maximum logging cost to roadside	_____ $/$m^3$

4. Harvesting Feasibility

Slope	maximum 40%
Soils	Moderate to Low categories for displacement, surface erosion, mass wasting and forest floor displacement These categories can be higher if cable systems are feasible or proposed
Other	
Access:	Stand edge <1/2 km from existing road

Other

5.Forest Health Concerns

What are the breakpoints or maximum levels of various forest health factors that would preclude a commercial thinning entry?

Disease

Insects

Windthrow

Snow Break

6. Other Comments, Recommendations, Concerns, etc.

APPENDIX B

Arrow TSA cruising contract Schedule A

SCHEDULE A

SERVICES

Attachment to minor services contract dated _____ for commercial thinning timber cruising in Arrow Forest District.

The Contractor will:

1. Adhere to the *Forest Service Cruising Procedures and Cruise Compilation Manual* (updated April, 1997) as well as the *Nelson Region Cruising Guidelines* for implementation.

2. Employ experienced and competent personnel with a minimum of two years cruising experience for works performed under this contract. Resumes of these personnel shall be provided by the contractor and be appended to this contract. The contractor shall designate a representative for liaison with the Ministry for the term of this contract. Personnel changes cannot be made without prior written consent of the forest officer.

3. Provide Workers' Compensation for all personnel involved in the project and ensure the activities adhere to W.C.B. requirements.

4. Attend and participate in a pre-work conference with the Forest Service contract administrator to review contract particulars and the scheduling of the phases.

5. Liquidated Damage Clause: "A deduction of $200.00 per day may be made by the Ministry from the contract price for elapsed time, after the date specified for completion, for non-completion of the contract, except in the case of conditions beyond the control of the Contractor. Such deduction is hereby agreed upon as liquidated damages."

6. Submit all original survey cards, working maps and notes upon completion of the project. Such information will become the property of the Ministry of Forests.

7. The Ministry reserves the right to terminate this contract upon the completion of any unit, based upon re-evaluation of the contract area development priority and review with other agencies and resource users. Upon termination, the Ministry shall not be obliged to make any further compensation to the contractor other than the payment for any work the contractor has already completed to the satisfaction of the Province.

CRUISING

1. The Contractor shall prepare a cruise plan for the blocks identified in Appendix A *for approval by the Contract Officer. The cruise plan must be designed to achieve* sampling error objectives are at a minimum sampling intensity of one plot every 100 meters (one plot per hectare). This sampling intensity does not forgo the requirement to establish a minimum of ten (10) cruise plots per block.

2. The Contractor shall complete a timber cruise of the blocks identified in Appendix A. Cruising must be done in accordance with the standards described in *the Forest Service Cruising Procedures and Cruise Compilation Manual* and the *Nelson Region Cruising Guidelines.*

3. Submit all plot cards, pre-compilation for checking. The operational cruise will be check cruised by the Ministry prior to completion of the cruise if possible.

4. Collect information to a utilization standard 7.5 cm d.b.h.

5. All mapping and field marking standards shall be in accordance with the *Forest Service Cruising Procedures and Cruise Compilation Manual*. All lines to be clearly flagged along the entire length with blue ribbon. All stations to be clearly marked with metal tags and blue and orange ribbon.

6. Submit a magnetic copy of the cruise data in a format prescribed by the Regional Manager. The magnetic copy must be in an approved ASCII that is compatible for downloading onto the Ministry's mainframe computer cruise program. The Contractor is not required to compile the results of the cruise.

7. Sample tree details shall be collected for two trees per plot. One of the trees must be a top height tree (unless no suitable tree exists in the plot). The other tree must be a suitable codominant tree of the leading species. Both trees must exhibit suitable characterics to be classified as Leave trees. In addition to the standard information collected for the sample trees, the contractor shall also collect and record the growth rate information for those trees on the back of the FS 205. The top height tree information shall be clearly identified by an * beside the tree number on the plot cards.

8. All trees within each plot that are greater than or equal to 7.5 cm dbhob will be measured and recorded on the FS 205 plot card. BAF 3 prism is recommended to ensure sufficient number of trees are measured in each plot and to develop a reasonable stand and stock table and cut/leave volume estimates. The same BAF shall be used for each type. The intent is to be able to include 8-10 merchantable trees per plot.

9. The Contractor shall identify appropriate Cut and Leave trees within each cruise plot. The general guideline is to prescribe a residual basal area of 10 - 15 m2 or 600-800 residual trees per hectare at approximately 4 metres between Leave trees.

Column 59 on the FS 205 shall be used to identify Cut and Leave trees. Leave trees, for this purpose, are dominant or codominant, exhibiting good form, health and vigour at least two meters away from any other designated Leave tree. Leave trees must also have >25% live crown and a height/diameter ratio <100. Where all these characteristics are not exhibited on any trees, then the largest, healthiest trees shall be classified as Leave trees. All deciduous trees should be considered as Cut trees.

10. A centre nested 3.99 m radius (0.005 ha.) fixed radius subplot to record the small tree and regeneration information is required at each main plot. The information to be collected is for trees that are less than breast height or less than 7.5 cm dbhob and will be summarized by species. All small trees taller than breast height but less than 7.5 cm dbhob will have species, average height and average diameter recorded (eg: 10 Df; average height 2m; average diameter 6 cm). For small trees below breast height only the total trees and average height will be recorded. Many small trees shorter than breast height can be recorded together (eg.: 50 Df ; 0.75 m tall).

11. Live crown ratio (LCR) codes will be collected for each tree and the appropriate codes will be recorded in column 51 of the FS 205 cruise tally card. The live crown ratio is defined as the ratio of live crown to total tree height. The live crown ratio codes to be used are:

LCR %	1-10	11-20	21-30	31-40	41-50	51-60	61-70	71-80	81+
Code	1	2	3	4	5	6	7	8	9

12. The Contractor shall record the average percent slope, aspect, elevation for each block.

13. The Contractor shall record the average Biogeoclimatic zone, subzone, variant and site series for every strata within each block.

14. The Contractor shall identify the number of trees in each plot that have confirmed evidence of Armillaria root disease infection. Infected trees shall be identified in column 60 of the FS 205 cruise card.

SCHEDULE B

SERVICES

Attachment to minor services contract dated ---------- for commercial thinning timber cruising in Arrow Forest District.

Unit	Map id	Area (Ha.)	Minimum number of plots	Price per plot or per hectare $	Unit Price $
A	82F023 polygon #466	15	15		
B1	82F023 opening #31	10	10		
B2	82F023 opening #31	8	8		
C	82F023 polygon #147	10	10		
D1	82F023 opening #36	16	16		
D2	82F023 opening #36	20	20		
E	82F023 polygon #96	20	20		
F	82F005 polygon # 531	10	10		
		Total ha.: 109	Minimum plots :109		Total Price $

APPENDIX C

Cranbrook TSA reconnaissance survey and cruising contract Schedule A

SCHEDULE A

SERVICES

Attachment to minor services contract dated _____ for commercial thinning reconnaissance surveys and timber cruising in Cranbrook Forest District.

PHASE 1 RECONNAISSANCE

1.01 The Contractor will be responsible for doing an initial field reconnaissance in order to determine the feasibility of commercial thinning and completing the cruise phase of the contract.

1.02. Criteria that determine that the stand is not feasible for commercial thinning include:

- Stocking density of 600 stems per hectare or less
- Crown closure class of 4 or less
- Site index of <11m at breast height age 50
- Live crown on the dominant and codominant trees <20%
- Height/diameter ratio of dominant and codominant trees >100
- Greater than 10% of the dominant or codominant trees exhibit above-ground symptoms of *Armillaria* root rot. The presence of *Armillaria* must be confirmed by the contractor.

1.03 Depending on the combination of the above and other factors, if the stand is determined to not be suitable for commercial thinning, the stand will be placed into the following categories:

- Category 1 Sawlog
  - Stocking density of 600 stems per hectare or less and/or
  - Crown closure class of 4 or less
  - Age > 80 years

- Category 1 Pulpwood
  - Site index of <11m at breast height age 50 and/or
  - Live crown on the dominant and codominant trees <20% and/or
  - Height/diameter ratio of dominant and codominant trees >100 and/or
  - Stocking density >3,000 stems per hectare

1.04. The Contractor shall, for each stand determined in the reconnaissance survey to not be suitable for commercial thinning, establish two cruise plots in representative areas of the stand to support the determination.

1.05. The Contractor shall, for each stand determined in the reconnaissance survey to not be suitable for commercial thinning, prepare a one page summary report detailing the criteria and results of the reconnaissance survey and cruise that were used to make that determination.

PHASE 2 CRUISING

2.01. The Contractor shall prepare the cruising plan and cruise design maps and complete an operational timber cruise of the blocks identified in Appendix A. Cruising must be done in accordance with the standards described in *the Forest Service Cruising Procedures and Cruise Compilation Manual* and the *Nelson Region Cruising Guidelines.*

2.02. The Contractor agrees to provide to the District Manager two (2) copies of a final cruise map prepared to the standards described in Appendix __. The final cruise map will be at a scale of 1:10,000 and the 1:20,000 scale map shall be a forest cover map.

2.03 The Contractor shall use the Forest Service cruise tally sheets (FS 205). The Forest Service will provide the cards. The Contractor must fully complete the cruise identification section of all cruise cards.

2.04. The Contractor shall prepare a cruise plan for the blocks identified in Appendix A for approval by the Contract Officer. The cruise plan must be designed for a sampling intensity of one plot every 150 meters (one plot per 2.25 hectares). The cruise plan and map must be approved in writing, prior to the commencement of the field work. Cruise plan approval does not waive the requirement of establishing a minimum of 10 plots per block.

2.05. Additional data collected shall include the following:

a. Sample tree details shall be collected for two trees per plot. One of the trees must be a top height tree (unless no suitable tree exists in the plot). The other tree must be a suitable codominant tree of the leading species. Both trees must exhibit suitable characteristics to be classified as Leave trees. In addition to the standard information collected for the sample trees, the contractor shall also collect and record the growth rate information for those trees on the back of the FS 205. The top height tree

information shall be clearly identified by an * beside the tree number on the plot cards.

b. All trees within each plot that are greater than or equal to 7.5 cm dbhob will be measured and recorded on the FS 205 plot card. BAF 3 prism is recommended to ensure sufficient number of trees are measured in each plot and to develop a reasonable stand and stock table and cut/leave volume estimates.

c. Live crown ratio (LCR) codes will be collected for each tree and the appropriate codes will be recorded in column 51 of the FS 205 cruise tally card. The live crown ratio is defined as the ratio of live crown to total tree height. The live crown ratio codes to be used are:

LCR %	1-10	11-20	21-30	31-40	41-50	51-60	61-70	71-80	81+
Code	1	2	3	4	5	6	7	8	9

d. The Contractor shall identify appropriate Cut and Leave trees within each cruise plot. Column 59 on the FS 205 shall be used to identify Cut and Leave trees. The general guideline is to prescribe a residual basal area of 10 - 15 m2 or 600-800 residual trees per hectare. Leave trees, for this purpose, are dominant or codominant, exhibiting good form, health and vigour at least two meters away from any other designated Leave tree. Leave trees must also have >25% live crown and a height/diameter ratio <100. Where all these characteristics are not exhibited on any trees, then the largest, healthiest trees shall be classified as Leave trees.

e. A centre nested 3.99 m radius (0.005 ha.) fixed radius subplot to record the small tree and regeneration information is required at each main plot. The information to be collected is for trees that are less than breast height or less than 7.5 cm dbhob. All small trees taller than breast height but < 7.5 cm dbhob will have species, height and diameter and 5 year height increment recorded. Small trees below breast height will be recorded with a diameter of .1 and the appropriate height. Many small trees shorter than breast height can be recorded together (eg.: 50 Df ; 0.75 m tall).

f. The average percent slope, aspect, elevation for each block.

g. The average Biogeoclimatic zone, subzone, variant and site series for each block.

h. The number of trees in each plot that exhibit signs of Armillaria root disease infection. Infected trees shall be identified in column 60 of the FS 205 cruise card.

2.06. The Contractor shall submit all plot cards, pre-compilation for checking. The operational cruise will be check cruised by the Ministry prior to completion of the cruise if possible.

2.07. All field marking standards shall be in accordance with the *Forest Service Cruising Procedures and Cruise Compilation Manual*. All stations to be clearly marked with metal tags and blue and orange ribbon.

2.08. Submit a magnetic copy of the compilation in a format prescribed by the Regional Manager. The magnetic copy must be in an approved ASCII format that is compatible for downloading onto the Ministry's mainframe computer cruise program. The Contractor is not required to compile the results of the cruise

OTHER

3.01. Prior to commencement of work, the Contractor shall meet with the Ministry Officer to review the contract terms and to jointly develop the Work Progress Plan.

3.03. The Contractor agrees to provide to the District Manager all original cruise tally cards and field notes prepared to the requirements in effect at the time of cruising, in accordance with regional and Ministerial Policies, Appendix ___.

3.04. The Contractor agrees to satisfactorily complete all phases of the work and to present to the District Manger all documentation described in parts _____ of this schedule by no later than _____.

3.05. Payment for the reconnaissance and will not be made until the documentation is delivered to the District Manager.

3.06. Air photos and maps of the areas are available for review at the Ministry of Forests office.

3.07. The Contractor is the Prime Contractor for purposes of the Worker's Compensation Board and shall comply with all WCB requirements.

3.08. If portions of the contract can not be completed due to weather conditions partial payments may be considered. Partial payment will be based on the percentage of each phase completed and is set out in Schedule B.

3.09. In the event the contract is cancelled by the District Manager for non-compliance with any contract conditions, the security deposit shall be the subject to forfeiture in whole or in part at the discretion of the District Manager.

3.10. Payment will be made following satisfactory completion of all work and submission of an invoice in triplicate for the agreed amount.

3.11. All documents submitted to the Ministry of Forests become the property of the Province, and as such, will be subject to the disclosure provision of the *Freedom of Information and Protection of Privacy Act*.